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Executive Summary

Expansion of poultry house operations and use of litter as a soil amendment in Accomack County Virginia has raised concerns for water quality impacts on both seaside and bayside of the Eastern Shore of Virginia (ESVA). This ongoing investigation is examining freshwater stream water quality in Accomack Virginia to identify water quality impairments from poultry operation storm water runoff. Previous sampling data from 2019 has been integrated into this report. Sampling in 2020 followed an extended drought period (base flow) and two inch rainfall events (storm flow) in streams at road crossings in Accomack County Bayside and Seaside drainages. Dissolved Ammonia, Dissolved Nitrite + Nitrate, Total Nitrogen, Total Phosphorous, and Turbidity were determined by laboratory analysis. Temperature, Salinity, Dissolved Oxygen, and pH were recorded in the field, and flow rates determined. Estimates of land cover in the drainages for these streams were used to determine correlations between stream water nutrient levels and the presence of poultry operations, agricultural fields, residential housing, forest, and swamps. No overall effect of poultry operations could be detected. Stable Isotope data suggest little to no input to stream particulate matter from poultry litter or poultry ammonium deposition. Rainfall tended to dilute nitrogen concentrations in streams indicating a ground water source, although total nutrient loading increased with the increasing flow. Turbidity and particle associated phosphorous showed the most dramatic changes with storm events. Data on Seaside ESVA watersheds for stream nitrate values from ten years ago had an overall average value slightly lower than the overall value for the present study. Stream water quality on Bayside will be assessed again in 2021, and will expand to include Northampton County streams with funding from the National Fish and Wildlife Foundation (NFWF).

Background

Expansion of poultry house operations and use of litter as a soil amendment on the Eastern shore of Virginia (ESVA), as well as elsewhere in the Chesapeake Bay watershed, has raised concerns for water quality impacts on both seaside and bayside of the Eastern Shore of Virginia (ESVA) where harvesting marine resources and aquaculture operations may be affected. Between 2014 and 2018, 218 houses were built in Accomack County, VA. The expansion has slowed, with only 11 of the 218 being permitted in 2018, and an additional 8 houses were permitted in 2019, bringing the total number of permitted sites to 87, with 480 houses. No new houses were permitted for 2020, but permits were issued for 8 new manure sheds. The newer houses are larger, holding more birds. Of those permitted and constructed, the poultry industry records for Accomack County at the end of 2020 (Delmarva Poultry Association, DPA; https://www.dcachicken.com) showed 67 growers operating 403 houses in production with a maximum housing capacity of 15,675,337 birds.

The aerosols, dust, and litter from the poultry houses are potential sources of nitrogen, phosphorous, and fecal contamination to watersheds and receiving waters. Siting regulations, storm water controls, and management of litter storage, handling, and application are designed to limit these impacts, yet no analysis has been implemented to verify the efficacy of these protective measures. This investigation extends and expands a VIMS ESL initial effort to sample ESVA watersheds and determine nitrogen and phosphorous concentrations in freshwater streams. Data collected in 2018 and 2019 were included in the Accomack County Annual Poultry Report for those years (Snyder and Ross, 2019b; 2020b). Accomack County has provided funding to sample streams in that county for storm events and dry periods (base flow) in 2020. Base flow reflected ground water sources to the stream flow, and storm events contributed runoff water in addition to base flow and increased groundwater flow from the hydraulic loading of storm water infiltration.

This report is submitted to Accomack County, and is publicly available from the William & Mary Scholarworks website in their library system. In addition to assessing any impacts from poultry operations, the assessments should be useful for local and regional environmental management and as baselines for Virginia's Draft Chesapeake Bay 2020-2021 Programmatic Milestones.

Methodology

Stream crossings at roadside right of ways were targeted for sampling. The location of samples taken in 2020 are shown in Figure 1. At each location, latitude and longitude coordinates were recorded with a handheld GPS. A YSI multiparameter water quality meter was used to record temperature, salinity, dissolved oxygen and pH of stream flow at the time of sampling. This meter was maintained and calibrated by trained ESL staff.

Sub-surface water samples for total nitrogen and total phosphorous were taken with clean 1 L polypropylene bottles by a gloved technician that were rinsed three times with site water prior to filling. All samples were placed on ice for transport to the ESL for processing. In the lab, sample water for Total Nitrogen (TN) and Total Phosphorous (TP) were taken from agitated 1 L bottles and frozen in 125 ml bottles. Dissolved ammonia and NOx (Nitrate + Nitrite) sample water was filtered into 60 ml polypropylene bottles with a 60 cc syringe and either or both 13 mm and 25 mm stainless steel swinnexes holding a Whatman GF/F filter. Thirteen mm filters were used until clogged and retained for elemental analysis of particulate carbon and nitrogen and their stable isotopes. All samples were kept frozen at -20 degrees C until transfer (frozen) to analytical services at VIMS Gloucester Point for analysis in a VELAP certified laboratory (ID #450151) with a Skalar Auto Analyzer using standard methods. Unfiltered sample water was also analyzed for turbidity at ESL using a La Motte 2020e Turbidity meter with the manufacturer's standards and following the manufacturer's procedures.

Rainfall records were obtained from archived records for Melfa Airport: https://weatherspark.com/h/td/147126/Historical-Weather-at-Melfa-Accomack-Airport-Virginia-United-States-Today. and using the Community Collaboratoive Rain, Hail, & Snow Network (CoCoRaHS; https://www.cocorahs.org) covering Accomack County (Figures 2 and 3).

Flow rates were determined for culverts and rectangular raceways under roads by determining the cross-sectional area of flowing water and the flow speed by timing the transit of a semi-buoyant tracer (fine pine shavings). Internet webpages with calculators (https://planetcalc.com/1421/; https://www.mathopenref.com/segmentareaht.html) were used to determine the area of circle segments for round culverts based on water depth, water width, and culvert diameter.

Data were compiled in MS Excel spreadsheets. SAS Institute JMP software was used for statistical analyses. Graphical plots were produced with Synergy KaleidaGraph software. GIS plotting of data and estimates of land use areas were accomplished with ESRI ArcMap software. Sampling locations plotted in GIS on a base map were overlaid with NHD Stream flow lines for seaside and bayside ESVA. Topographic maps and VBMP 2017 aerial imagery were also used to define watersheds for sample locations. Locations of permitted poultry operations, for which DEQ site visits have been made to confirm activity, are obtained from VA DEQ.

Characteristics of watersheds draining to sampling points were estimated by visual inspection of watersheds using topographic maps and the VBMP 2017 aerial imagery as base maps. Percent coverage of human residences, agricultural fields, forest, and swamp was recorded. Human residences were assumed to represent septic tank drain field inputs as well as lawn and garden fertilizer amendments, and animal/bird waste. Agricultural field area was assumed to represent fertilizer, manure, and other soil amendments as well as sediment runoff. Swamp coverage may be underrepresented due to a significant forest area that is periodically flooded by runoff on the ESVA. Forest area is often restricted to linear strips in stream gulleys, where ground water seepages are a major source, but storm water runoff could pass unchanged. Each sampling station is scored Y or N for presence or absence, respectively, of poultry operations anywhere upstream, regardless of distance. Data were log transformed as appropriate prior to analysis, and geometric means were calculated to determine central tendencies.

Limited data on groundwater nitrate levels under the ESVA show relatively high values (>10 mg/L; Ator and Denver, 2015). Groundwater contributions to steam flow are variable and largely unknown but considered a major portion of the freshwater discharge to surface waters for the ESVA, whereas rivers dominate nutrient loadings in many other areas. Nitrogen as nitrate in groundwater contributes about 70% of streamflow nitrogen on the Delmarva as a whole, whereas phosphorous is mainly associated with storm water runoff (Ator and Denver, 2015). A dry season sampling event would isolate groundwater flow from storm water runoff. All of the storm flow samples taken in 2020 immediately followed ~2" rainfall events (Figures 2 and 3), and so would capture storm water runoff combined with groundwater flow. Ascribing source to nutrients in flowing streams is not an exact process, but the assessment identifies streamsheds with high turbidity and nutrient levels that can provide a basis for screening potential sources and directing resources for remedial action.

Results and Discussion

After approximately 30 days of drought, base flow in Accomack streams totaled 43,377 liters/min (11,459 gallons/min) or 3.8% of the storm flow at 1,144,153 liters/min (302,253 gallons/min) after 2" rainfall events. This increase in stream flow represents both stormwater runoff into stream basins and the hydraulic pressure of infiltrating water accelerating ground water discharge. Since these data only represent streams with access at road crossings, they come from only a fraction of all streams in the county. It is considered that they represent a random sample of all streams and were taken at random positions between headwaters and discharge to tidal waters. The data, as single point measurements in streams, also do not reflect any downstream additions or attenuation with distance. Storm flow after a prolonged drought will also carry the accumulated organic detritus from the dry period, and may be more of an extreme case than repeated storm events that regularly wash through the system.

The change in flow rates from base to storm affected stream turbidity and nutrient concentration values (Table 1). Base flow water quality parameters largely reflect ground water concentrations of nutrients, but also would be affected by in-stream processes such as heterotrophic mineralization of organic matter supplying nitrogen and phosphorous, and uptake of nutrients by in stream autotrophs and roots of stream basin vegetation. Turbidity at base flow would reflect stream bank erosion and resuspension of bottom sediments. Average (geomeans), Standard Deviations, Minimum, Maximum and ratios of Storm/Base flow values for all parameters are presented in Table 1. Graphic plots showing the spatial distribution the values for individual samples are should in Figures 4-6 and 8-10. Average flow by station increased by a factor of 32x from 110 L/min to 35,198 L/min (Table 1 and Figure 4). This increased flow resulted in increased Turbidity values from an average of 3.99 NTU to 12.5 NTU, or approximately 3x (Table 1 and Figure 5). Average Total phosphorous also increased from 0.075 mg/L to 0.355 mg/L or 4.8x (Table 1 and Figure 6). Phosphorous is typically insoluble in freshwaters, and the increase is largely due to the association of phosphorous with particulate matter causing the higher turbidity values, whereas total nitrogen did not show any clear pattern associated with turbidity (Figure 7). The loading rate for phosphorous (flow x concentration) also increased from 1.3 g/hr to 58.6 g/hr, or 47x.

Nitrogen species either remained the same or decreased in concentration with the increase in storm water flow (Table 1.). Average Total Nitrogen (dissolved + particulate) concentration remained the same (2.007 to 1.996 mg/L; 0.995x), while dissolved Ammonia (NH_3) and Oxidized Nitrogen ($NO_2 + NO_3 = NO_x$) decreased with higher flow rates. Ammonia dropped from 0.147 to 0.061 mg/L or 0.41x, and NOx concentrations dropped from 1.453 to 0.774 mg/L or 0.53x while the percent of TN for NH_3 went from 7.3% to 3.06% and the percent of TN for NO_x went from 72.4% to 38.8%. This represents a shift from dissolved to particulate nitrogen in the stream with storm water flow, likely coming from organic detritus accumulated during the drought period in the stream basins and washed into the streams from the landscape. The drop in stream concentrations for NH_3 and NO_x show dilution by storm water flow for these dissolved constituents coming from heterotrophic respiration in streams and wetlands (NH_3), and ground water (NO_x) during base flow conditions. Spatial distribution and spatial variance of the nitrogen in the streams are shown in Figures 8-10.

A previous investigation of baseflow water quality on Seaside ESVA conducted in 2001-2002 (Table 2.; Stanhope et al., 2009), yielded slightly higher concentrations of nitrate than the overall average NO_x for the present study (NO_x = nitrite + nitrate; nitrite is typically a minor component). Variance in these data however, suggests the difference is not significant, but it is encouraging to see lower overall values rather than increases.

Although the concentrations of dissolved nitrogen species decreased and total nitrogen remained unchanged, loading rates of all nitrogen forms increased because of the increased flow, with a 5.1x increase in NH_3, 6.9x increase in NO_x, and a 16.5x increase in TN (Table 1). Increases in overall loading rates (sum of all streams sampled) with storm flow for Seaside, Bayside, and overall also reflect the dynamics of the averaged values (Table 1.). Nitrogen loading was somewhat lower for Bayside drainages than Seaside drainages for both base and storm flow, although base flow for both was identical for phosphorous loading, and Bayside storm flow loading increasing to only half the Seaside storm flow loading (Table 1).

Table 3 lists the top sample locations for parameter values recorded for 2020, which may be of interest for remedial or restoration action with Chesapeake Bay cleanup funds or other sources. Note that those samples taken in streams draining watersheds with poultry operations are a small fraction of those listed, consistent with other indications of potential poultry operations impacts (Tables 4 and 5). Overall, there was no significant effect of poultry operations on groundwater inputs (base flow) or stormwater runoff (storm flow), with poultry watersheds with consistently the same or lower concentrations than non-poultry watersheds (Table 4). For all watersheds with poultry operations (Table 5), those with storm flow values exceeding the top 95% limit above the geomean numbered 12 of 52,

Table 5 lists all the stations where poultry operations were located anywhere in the watershed upstream of the sample location. Total nitrogen and total phosphorous values that exceed the 95% limit (two standard deviations) above the geomean for all values are shaded, and only those from 2020 are discussed here. Previous year's reports provided information for those years. For total nitrogen, 12 of 15 stations fell into this category. For total phosphorous, 5 of 52 stations fell in this category. For 2 stations, sample results showed both elevated nitrogen and phosphorous (Table 5). Further details on these locations are provided as part of this assessment:

- Station 30 is the North branch of Taylor Creek where it crosses Bobtown Road with potential input from a poultry operation located along Pungoteague Road. In 2019 this station exceeded both total nitrogen and total phosphorous 95% limits, and in 2020 exceeded the 95 percentile of all storm flow values for TN.

- Station 36 is on Rattrap Creek at Drummondtown Road with potential drainage from housing along Locustville Road and 2 poultry operations south of Rattrap Creek.
- Station 40 was reported for the 2019 value in the previous year's report.
- Station 50 is located on Lee Mont Branch next to the town of the same name with a poultry operation upstream.
- Station 57 is located at the intersection of Big Road and St. Thomas Road on Katy Young Branch, draining from the town of Parksley and poultry operations east of Hopetown Road.
- Station 77 is located in Assawoman Creek where it crosses Atlantic Road receiving drainage from the town of Temperanceville and multiple poultry operations. The Tyson's processing plant is unlikely to drain into this system.
- Station 91 is located in Frogstool Branch where it crosses Seaside Road, near the intersection of Frogstool Road. There is a poultry operation on the west side of Seaside Road, and the town of Keller is part of this watershed.
- Station 123 is located on an unnamed branch leading to Jimmy's Gut where it crosses Big Road as a ditch SW of Hopetown with a potential connection to poultry operations east of Hopetown Road by drainage ditches.
- Station 138 is located in Bullbegger Creek where it crosses Holland Road, receiving drainage from a poultry operation via cross field ditches and the town of New Church and additional poultry operations east of that town.

The corresponding base flow data for these stations suggests that some or all of these values may be accounted for by groundwater sources.

Correlation (bivariate) analysis of landuse/landcover variables (x) upstream of sample locations and nutrient values (y) were non-significant ($P > 0.05$) due to the variability in the data although patterns in the relationships are worth noting (Figure 11).

Turbidity values (Figure 11, left column) as a function of residential density showed similar slopes for both base and storm flow, essentially no or a slightly decreasing effect, although the overall turbidity values increased with storm flow resulting in a parallel line above the base values. For forest and swamp cover, turbidity values were relatively flat (no increase) with increasing coverage, although turbidity values decreased with increasing cover for both under storm flow conditions, indicating the value of these habitats for filtering storm water flow. The only increase in turbidity with storm flow is seen for the increasing coverage of agricultural fields and indeed the highest values recorded were associated with a high percentage of field cover, a reflection erosion of tilled lands.

Total nitrogen values (Figure 11, mid column) remained unchanged and unresponsive to increasing coverage of fields, forest, or swamps, but total nitrogen in streams changed from decreasing to an increasing trend with storm flow with increasing residential coverage.

Total phosphorous (Figure 11, right column) showed very little trend line response overall to increasing coverage of any type, but the highest phosphorous values were associated with highest % field coverage, consistent with increased turbidity as noted above.

Stable isotope ratios of ^{15}N:^{14}N and ^{13}C:^{12}C have been used to track inputs from sources to receiving waters, and the values recorded for in stream particulates in this study are presented in Figure 12. These data points are accompanied with high variance as the concentrations of carbon and nitrogen for many samples were low. The isotope signatures changed slightly with storm flow as seen in the shift in the pattern of blue (base) and red (storm) data points, and with the average carbon signature changing from -29.4 per mil to -27.5 per mil. The nitrogen signature was largely unchanged from 5.32 mil to 5.7 per mil. Values for Delmarva chicken litter from Fertig et al. (2014) are shown in green as well separated data, and suggest very little input of chicken litter nitrogen or carbon to stream water particulates (Figure 12). The three points within the range of poultry litter nitrogen are from stations in watersheds with no poultry operations, although litter application to fields was possible. Metazoan trophic processing of the litter nitrogen would result in a ~+4 per mil shift away from the stream particulate values, although microbial trophic processing may result in less dramatic shifts or none at all (Hoch et al., 1996; Gutiérrez-Rodríguez al., 2014).

Cravota (1997) reported carbon and nitrogen isotope values for in-stream particulates from fertilizer land use areas as -25.33 per mil ^{13}C and 4.43 per mil ^{15}N, and septic system land use values of -26.98 per mil ^{13}C and 2.54 per mil ^{15}N. This suggests that these sources of nitrogen to stream particulates may have a greater influence in the streams in Accomack County, with inorganic fertilizer being the closest match. The best match to in-stream particulate data provided by Cravota (1997) was to forest land particulates for carbon at -27.31 per mil ^{13}C, suggesting most of the particulate matter in the ESVA stream basins is of terrestrial woodland material. This conclusion is also supported by the value of -26.85 per mil ^{13}C reported by Edje et al (2020) for terrestrial particulate matter in tributaries leading to the coastal bays of Maryland.

Conclusion

No overall effect of poultry operations on stream water quality could be detected. Stable Isotope data suggest little to no input to stream particulate matter from poultry litter. Rainfall tended to dilute nitrogen concentrations in streams indicating a ground water source, although total nutrient loading increased with the increasing flow. Turbidity and particle associated phosphorous showed the most dramatic changes with storm events. Data on Seaside ESVA watersheds for stream nitrate values from ten years ago had an overall average value slightly higher than the overall value for the present study. Stream water quality on Bayside will be assessed again in 2021, and will expand to include Northampton County streams with funding from the National Fish and Wildlife Foundation (NFWF).

References

Ator, SW and JM Denver. 2015. Understanding nutrients in the Chesapeake Bay watershed and implications for management and restoration- the Eastern Shore (ver. 1.2, June 2015): U.S. Geological Survey Circular 1406, 72 pp.

Cravota, C.A. III. 1997. *Use of Stable Isotopes of Carbon, Nitrogen, and Sulfur to Identify Sources of Nitrogen in Surface Waters in the Lower Susquehanna River Basin, Pennsylvania.* U.S. Geological Survey Water Supply Paper 2497. 99 pp.

Edje, B.O., A.B. Ishaque, and P. Chigbu. 2020. Spatial and temporal patterns of d^{13}C and d^{15}N of suspended particulate organic matter in Maryland Coastal Bays. *Water* 12:2345 doi: 10.3390/w12092345.

Gutiérrez-Rodríguez, A., M. Décima, B.N. Popp, and M.R. Landry. 2014. Isotopic invisibility of protozoan trophic steps in marine food webs. *Limnology and Oceanography* 59:1590-1598.

Hoch, M.P., R.A. Snyder, L. Cifuentes and R.B. Coffin. 1996. Stable isotope dynamics of nitrogen recycled during interactions among bacteria and protists. *Marine Ecology Progress Series* 132:229-239.

Snyder, R.A. and P.G. Ross. 2019a. *Water quality in an unnamed branch of Pungoteague Creek, Bobtaown Road and Hollies Church Road, VA*. VIMS ESL Technical Report #3. 9 pp. https://doi.org/10.25773/bhz7-8h64.

Snyder, R.A. and P.G. Ross. 2019b. *Water quality in southern Accomack County watersheds*. VIMS ESL Technical Report #2. 21 pp. https://doi.org/10.25773/cmm4-m650

Snyder, R.A. and P.G. Ross. 2020a. *Surface water nitrogen attenuation from the Accomack County, VA southern landfill groundwater discharge*. VIMS ESL Technical Report #5. 7 pp. https://scholarworks.wm.edu/reports/2049/

Snyder, R.A. and P.G. Ross. 2020b. *Water quality in Accomack County freshwater streams*. VIMS ESL Technical Report #4. 26 pp. https://scholarworks.wm.edu/reports/2050/

Stanhope, J.W., I.C. Anderson, and W.G. Reay. 2009. Base flow nutrient discharges from lower Delmarva Peninsula watersheds of Virginia, USA. *Journal of Environmental Quality* 38: 2070-2083. https://doi-org/10.2134/jeq2008.0358

Fertig, B., T.J.B. Carruthers, and W.C. Dennison. 2014. Oyster d^{15}N as a bioindicator of potential wastewater and poultry farming impacts and degraded water quality in a subestuary of Chesapeake Bay. *Journal of Coastal Research* 50: 881-892.

Table 1. A) Overall geomeans, standard deviations, minimum and maximum values determined for Turbidity, Flow rates, dissolved (NH_3, NO_x) and total nutrients (TN, TP), and B) loading rates (nutrients x flow) for Accomack streams after a month-long drought (Base Flow), and two 2" storm events (Storm Flow).

A)

Base Flow	Turbidity NTU	Flow L/min	NH3 mg/L	NOx mg/L	TN mg/L	TP mg/L	Loading NH3 g/hr	Loading NOx g/hr	Loading TN g/hr	Loading TP g/hr
Average	3.99	110	0.097	1.588	2.065	0.078	1.225	16.43	22.14	1.16
std	2.22	16.8	0.166	0.747	0.449	0.099	1.881	7.46	7.11	1.54
min	0.58	0.000	0.000	0.000	0.506	0.008	0.000	0.00	0.00	0.00
max	59.4	40,795	1.222	5.800	5.866	0.528	161	1352	1109	46.09
Storm Flow										
Average	12.5	35198	0.058	0.783	1.994	0.333	7.45	129.29	434.31	56.87
std	2.70	7.55	0.109	0.512	0.426	0.314	5.29	8.72	6.72	7.95
min	1.76	0.000	0.000	0.000	0.635	0.026	0.00	0.00	0.00	0.00
max	439	1,975,47	0.913	10.820	13.074	2.663	654	11402	27961	7227
Difference Storm/ Base										
Average	3.13	320	0.60	0.49	0.97	4.27	6.08	7.87	19.6	49.0
std	1.2	0.451	0.756	0.845	0.882	1.209	1.8	0.97	0.86	3.1

B)

	NH_3 kg/hr	NO_x kg/hr	TN kg/hr	TP kg/hr
Total Loading Seaside				
Base Flow	0.189	3.219	3.418	0.078
Storm Flow	2.959	36.215	84.844	24.430
Total Loading Bayside				
Base Flow	0.108	1.708	2.165	0.074
Storm Flow	1.290	27.814	70.202	12.307
Total Loading Accomack County				
Base Flow	0.297	4.927	5.583	0.152
Storm Flow	4.249	64.030	155.045	36.737

Table 2. Baseflow stream data for Seaside drainages ESVA collected monthly from May 2001 to May 2002 (extracted from Stanhope et al., 2009).

Location	**Latitude**	**Longitude**	**NO_3 mg/L Avg**	**NO_3 Stdev**	**NO_3 Min**	**NO_3 Max**
Taylor	37.3319	75.9142	1.00	0.37	0.05	1.38
Holt- Right	37.3883	75.8828	3.03	1.05	0.12	3.96
Holt- Left	37.3894	75.8906	1.37	0.51	0.06	1.92
Mill	37.4214	75.8589	0.05	0.06	0.00	0.18
Phillips	37.4625	75.8436	1.18	0.42	0.05	1.63
Greens	37.4914	75.8206	1.52	0.49	0.05	1.89
Partings	37.5266	75.7961	1.62	0.61	0.07	2.25
Machipongo	37.6036	75.7247	0.85	0.38	0.02	1.32
Nickawampus	37.6305	75.7081	2.47	0.94	0.14	3.68
Gargatha	37.7938	75.5677	2.80	1.05	0.07	4.01
Assateague 4	37.8533	75.5355	6.91	4.64	0.03	16.76
Assateague 3	37.8633	75.5325	2.76	0.93	0.07	3.73
Little Mosquito- Left	37.9511	75.4722	0.79	0.79	0.03	2.60
Little Mosquito- Right	37.9511	75.4533	3.96	1.36	0.16	5.28
Seaside baseflow Average			2.17			
Stdev			1.74			
Min			0.05			
Max			6.91			

Table 3. The ten highest sample values recorded for Turbidity, Ammonia (NH_3), Nitrite + Nitrate (NO_x), Total Nitrogen (TN) and Total Phosphorous (TP). Yellow indicates stations where poultry operations are located anywhere upstream in the watershed.

Base Flow

Station	Date	Lat	Long	Turbidity NTU
6	9-Jul-20	37.55697	-75.87808	27.6
49	30-Jun-20	37.77535	-75.59621	26
137	30-Jun-20	37.95353	-75.55781	22.1
121	23-Jul-20	37.79057	-75.69595	20.8
42	9-Jul-20	37.74620	-75.61068	19.6
1	30-Jun-20	37.52954	-75.80891	12.6
113	9-Jul-20	37.72509	-75.71867	12
110	30-Jun-20	37.71881	-75.66811	10.83
140	30-Jun-20	37.98698	-75.57219	10.32
67	30-Jun-20	37.84686	-75.54438	9.73
				NH3 mg/L
137	30-Jun-20	37.95353	-75.55781	1.22
6	9-Jul-20	37.55697	-75.87808	0.77
18	9-Jul-20	37.61758	-75.83267	0.68
136	30-Jun-20	37.93473	-75.49113	0.33
83	23-Jul-20	37.93756	-75.57971	0.29
111	30-Jun-20	37.72033	-75.66457	0.25
64	30-Jun-20	37.83409	-75.55099	0.18
42	9-Jul-20	37.74620	-75.61068	0.16
140	30-Jun-20	37.98698	-75.57219	0.15
115	23-Jul-20	37.73940	-75.73113	0.14
				NOx mg/L
74	30-Jun-20	37.86661	-75.53887	5.8
53	9-Jul-20	37.79018	-75.64936	5.764
58	30-Jun-20	37.79877	-75.58029	5.725
52	30-Jun-20	37.78551	-75.59048	5.075
117	30-Jun-20	37.75822	-75.61910	5.01
109	9-Jul-20	37.70772	-75.74055	4.248
76	30-Jun-20	37.86961	-75.53874	3.77
28	30-Jun-20	37.62627	-75.70315	3.74
107	30-Jun-20	37.69759	-75.66814	3.64
66	30-Jun-20	37.83754	-75.54620	3.46
				TN mg/L
53	9-Jul-20	37.79018	-75.64936	5.87
58	30-Jun-20	37.79877	-75.58029	5.40
117	30-Jun-20	37.75822	-75.61910	5.04
18	9-Jul-20	37.61758	-75.83267	4.87
74	30-Jun-20	37.86661	-75.53887	4.74
52	30-Jun-20	37.78551	-75.59048	4.17
109	9-Jul-20	37.70772	-75.74055	3.79
28	30-Jun-20	37.62627	-75.70315	3.47
66	30-Jun-20	37.83754	-75.54620	3.37
107	30-Jun-20	37.69759	-75.66814	3.34
				TP mg/L
137	30-Jun-20	37.95353	-75.55781	0.5276
121	23-Jul-20	37.79057	-75.69595	0.5226
113	9-Jul-20	37.72509	-75.71867	0.3712
6	9-Jul-20	37.55697	-75.87808	0.3082
115	23-Jul-20	37.73940	-75.73113	0.2277
83	23-Jul-20	37.93756	-75.57971	0.1679
140	30-Jun-20	37.98698	-75.57219	0.1406
47	23-Jul-20	37.76734	-75.68989	0.1382
79	23-Jul-20	37.90286	-75.57925	0.105
25	9-Jul-20	37.62207	-75.80722	0.1023

Storm Flow

Station	Date	Lat	Long	Turbidity NTU
33	12-Oct-20	37.64085	-75.71656	439
34	12-Oct-20	37.64890	-75.69581	262
142	12-Oct-20	37.69262	-75.66714	221
115	12-Oct-20	37.74503	-75.61940	204
36	12-Oct-20	37.65087	-75.68803	82.5
67	12-Oct-20	37.84688	-75.54445	49.7
42	12-Oct-20	37.74620	-75.61068	45.9
104	18-Sep-20	37.65802	-75.78542	33.3
90	12-Oct-20	37.58865	-75.75382	31
31	12-Oct-20	37.63651	-75.72430	30.2
				NH3 mg/L
49	12-Oct-20	37.77555	-75.59612	0.913
58	12-Oct-20	37.79888	-75.58031	0.4764
111	12-Oct-20	37.72020	-75.66451	0.4123
115	18-Sep-20	37.73940	-75.73113	0.41
8	12-Oct-20	37.56319	-75.77020	0.3071
28	12-Oct-20	37.62624	-75.70299	0.2789
52	12-Oct-20	37.78561	-75.59034	0.2159
42	12-Oct-20	37.74620	-75.61068	0.1979
69	12-Oct-20	37.67098	-75.71047	0.1498
33	12-Oct-20	37.64085	-75.71656	0.1392
				NOx mg/L
140	18-Sep-20	37.99708	-75.56757	10.82
8	12-Oct-20	37.56319	-75.77020	2.966
33	12-Oct-20	37.64085	-75.71656	2.71
1	12-Oct-20	37.52945	-75.80893	2.428
111	12-Oct-20	37.72020	-75.66451	2.224
34	12-Oct-20	37.64890	-75.69581	2.202
50	18-Sep-20	37.77596	-75.68267	2.16
130	18-Sep-20	37.87592	-75.59572	2.09
7	12-Oct-20	37.56170	-75.77154	2.082
69	12-Oct-20	37.67098	-75.71047	2.07
				TN mg/L
140	18-Sep-20	37.99708	-75.56757	13.07
8	12-Oct-20	37.56319	-75.77020	6.768
33	12-Oct-20	37.64085	-75.71656	5.42
1	12-Oct-20	37.52945	-75.80893	4.524
69	12-Oct-20	37.67098	-75.71047	4.464
111	12-Oct-20	37.72020	-75.66451	4.072
90	12-Oct-20	37.58865	-75.75382	3.904
34	12-Oct-20	37.64890	-75.69581	3.776
50	18-Sep-20	37.77596	-75.68267	3.60
28	12-Oct-20	37.62624	-75.70299	3.505
				TP mg/L
105	12-Oct-20	37.68235	-75.66444	2.663
139	18-Sep-20	37.97982	-75.57667	1.95
33	12-Oct-20	37.64085	-75.71656	1.716
8	12-Oct-20	37.56319	-75.77020	1.536
46	12-Oct-20	37.76377	-75.60874	1.395
69	12-Oct-20	37.66834	-75.71591	1.363
7	12-Oct-20	37.56170	-75.77154	1.176
36	12-Oct-20	37.65087	-75.68803	1.0186
77	12-Oct-20	37.87468	-75.52949	1.0142
69	12-Oct-20	37.66045	-75.73223	0.95

Table 4. Storm flow and base flow geomeans for streams with poultry operations anywhere upstream in the watershed compared to streams without poultry operations from 2019 and 2020 combined data.

Storm Flow	NH3 mg/L	NOx mg/L	TN mg/L	TP mg/L
No Poultry	0.073	0.815	1.845	0.242
stdev	0.130	0.591	0.481	0.279
Poultry	0.030	0.741	1.943	0.278
stdev	0.031	0.352	0.292	0.208
Base Flow				
No Poultry	0.121	1.251	1.897	0.082
stdev	0.261	0.721	0.497	0.091
Poultry	0.096	1.470	2.065	0.071
stdev	0.152	0.772	0.439	0.061

Table 5. Total Nitrogen (TN) and Total Phosphorous (TP) in streams with poultry operations anywhere in the upstream watershed. Yellow are storm flow TN values exceeding 95% of all values greater than the geomean. Blue are storm flow TP values exceeding 95% of all values greater than the geomean. Green are samples where both storm flow TN and TP exceed 95%.

Storm Flow						**Base Flow**		
Station	date	Lat	Long	TN mg/L	TP mg/L	date	TN mg/L	TP mg/L
3	20-Apr-19	37.5414	-75.7928	0.798	0.038			
4	20-Apr-19	37.5448	-75.7874	1.515	0.163			
4	12-Oct-20	37.5449	-75.7874	1.605	0.077	30-Jun-20	0.826	0.045
20	25-Jul-18	37.6195	-75.7344	0.179	0.019	20-Jul-18	1.557	0.205
20	20-Apr-19	37.6194	-75.7345	1.586	0.072			
20	12-Oct-20	37.6194	-75.7345	0.968	0.117			
29	25-Jul-18	37.6343	-75.8080	1.953	0.063	20-Jul-18	5.654	0.051
29	20-Apr-19	37.6341	-75.8082	1.328	0.217			
29	18-Sep-20	37.6342	-75.8080	2.351	0.317	9-Jul-20	2.700	0.062
30	25-Jul-18	37.6364	-75.8030	1.057	0.031	20-Jul-18	1.983	0.035
30	20-Apr-19	37.6363	-75.8025	8.974	1.817			
30	18-Sep-20	37.6365	-75.8027	2.745	0.106	9-Jul-20	2.020	0.033
36	25-Jul-18	37.6511	-75.6879	2.109	0.382	20-Jul-18	1.580	0.044
36	20-Apr-19	37.6509	-75.6879	1.689	0.118			
36	12-Oct-20	37.6509	-75.6880	1.663	1.019	9-Jul-20	0.585	0.065
37	20-Apr-19	37.6676	-75.7735	1.548	0.166			
37	18-Sep-20	37.6676	-75.7736	2.379	0.051	9-Jul-20	0.979	0.048
40	20-Apr-19	37.6837	-75.7506	2.608	0.631			
41	20-Apr-19	37.6849	-75.7532	2.539	0.459			
41	18-Sep-20	37.6849	-75.7532	1.613	0.272	1-May-20	1.517	0.097
50	24-Jul-19	37.7761	-75.6826	3.439	0.094			
50	18-Sep-20	37.7760	-75.6827	3.595	0.111	23-Jul-20	1.488	0.107
56	24-Jul-19	37.7947	-75.6462	1.906	0.158			
57	24-Jul-19	37.7978	-75.6670	2.436	0.100			
57	18-Sep-20	37.7978	-75.6669	2.960	0.090	23-Jul-20	2.910	0.038
59	24-Jul-19	37.8091	-75.6366	7.197	0.079			
60	24-Jul-19	37.8125	-75.5711	3.472	0.058			
60	12-Oct-20	37.8126	-75.5709	1.698	0.541	30-Jun-20	4.405	0.051
61	24-Jul-19	37.8257	-75.6499	3.484	0.170			
67	24-Jul-19	37.8470	-75.5444	1.819	0.085			
67	12-Oct-20	37.8469	-75.5445	1.589	0.374	30-Jun-20	2.497	0.050
73	24-Jul-19	37.8660	-75.5989	1.241	0.079	23-Jul-20	2.405	0.056
74	12-Oct-20	37.8669	-75.5389	1.324	0.103	30-Jun-20	4.740	0.025
76	24-Jul-19	37.8696	-75.5388	1.797	0.095			
76	12-Oct-20	37.8697	-75.5388	1.414	0.140	30-Jun-20	2.490	0.020
77	24-Jul-19	37.8747	-75.5297	1.431	0.121			
77	12-Oct-20	37.8747	-75.5295	2.141	1.014	30-Jun-20	2.310	0.032
78	24-Jul-19	37.8825	-75.6155	2.091	0.115			
79	24-Jul-19	37.9028	-75.5793	3.055	0.247			
79	18-Sep-20	37.9031	-75.5791	1.220	0.087	23-Jul-20	1.952	0.105
83	24-Jul-19	37.9375	-75.5797	1.344	0.122			
83	18-Sep-20	37.9378	-75.5796	1.744	0.208	23-Jul-20	1.473	0.168
88	25-Jul-18	37.6219	-75.8030	0.844	0.094			
91	12-Oct-20	37.5980	-75.7467	4.464	0.460	1-May-20	1.524	0.054
92	25-Jul-18	37.6137	-75.7313	0.724	0.033			
92	20-Apr-19	37.6137	-75.7321	1.250	0.045			
92	12-Oct-20	37.6137	-75.7318	1.460	0.125			
97	18-Sep-20	37.5749	-75.8744	1.334	0.159	1-May-20	6.380	0.035
106	18-Sep-20	37.6872	-75.7523	2.313	0.459			
123	18-Sep-20	37.8080	-75.6553	2.814	0.237			
134	18-Sep-20	37.9140	-75.5809	1.206	0.267			
138	18-Sep-20	37.9731	-75.5785	2.359	0.610	30-Jun-20	1.467	0.390

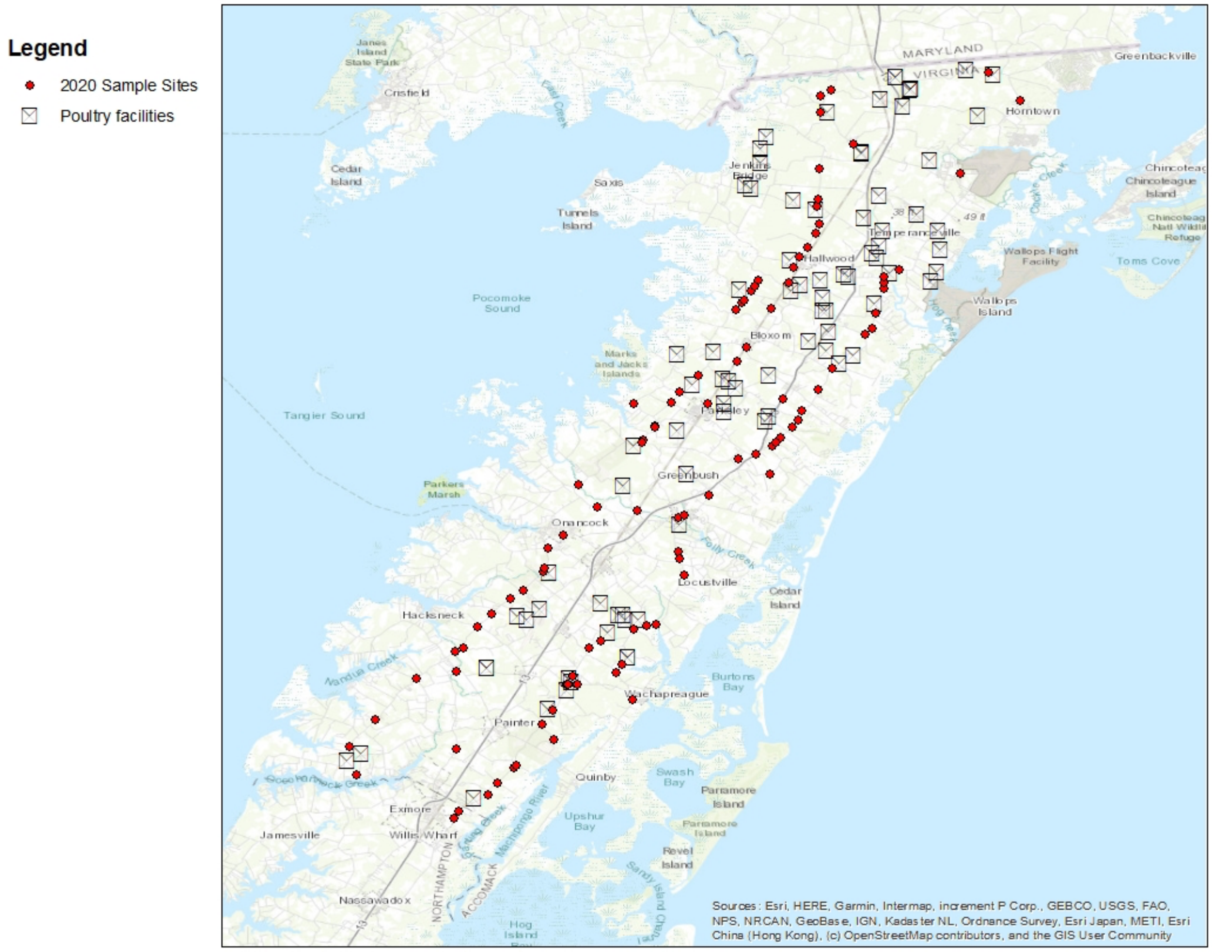

Figure 1. Stream-road crossing sampling locations during 2020. During drought (Base Flow), fewer stations held running water, and were a subset of this total.

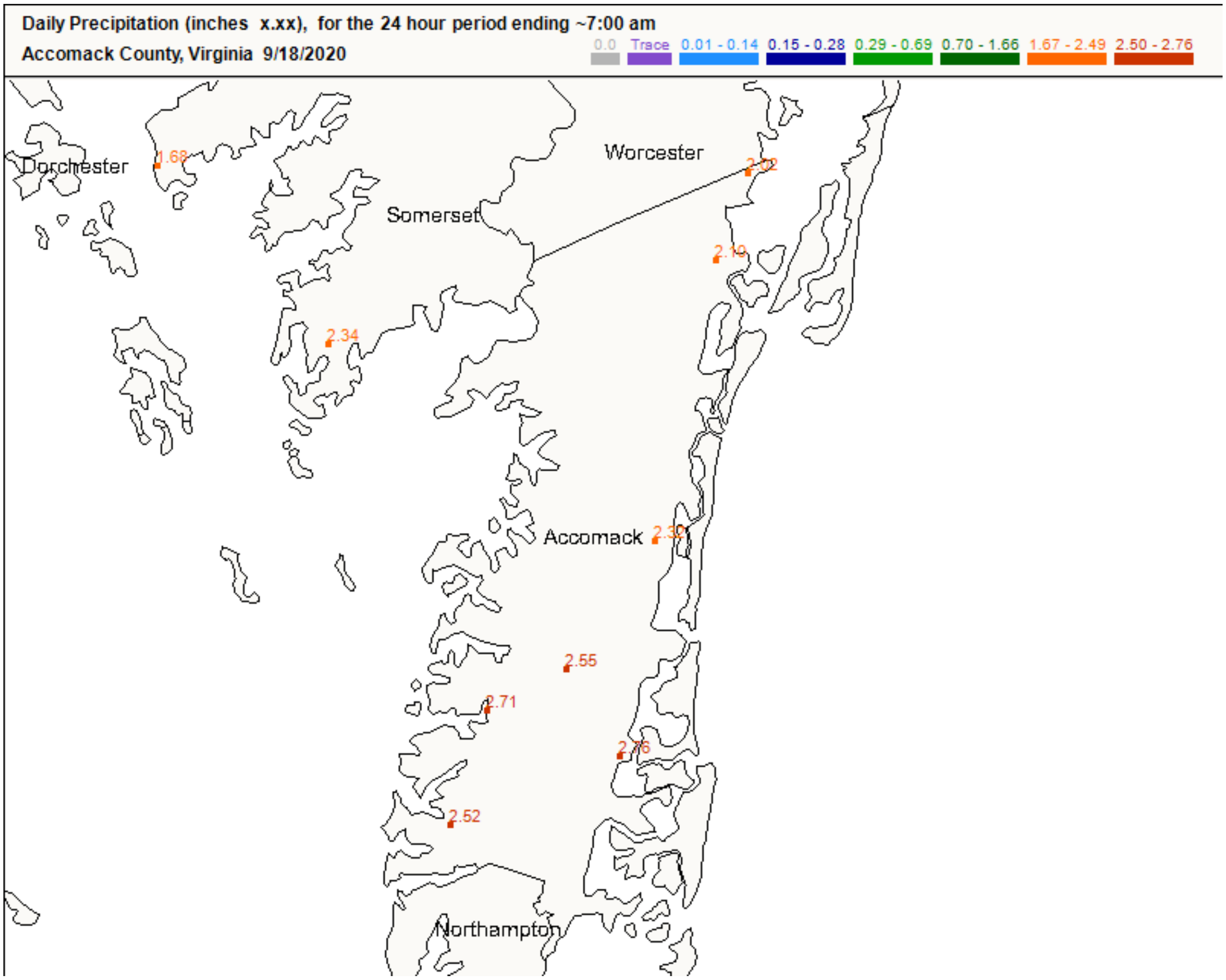

Figure 2. Rainfall records for the event 18 September 2020. Samples were being taken after these readings but before the storm completely passed. Map and data from: https://cocorahs.erams.com/locations/23480

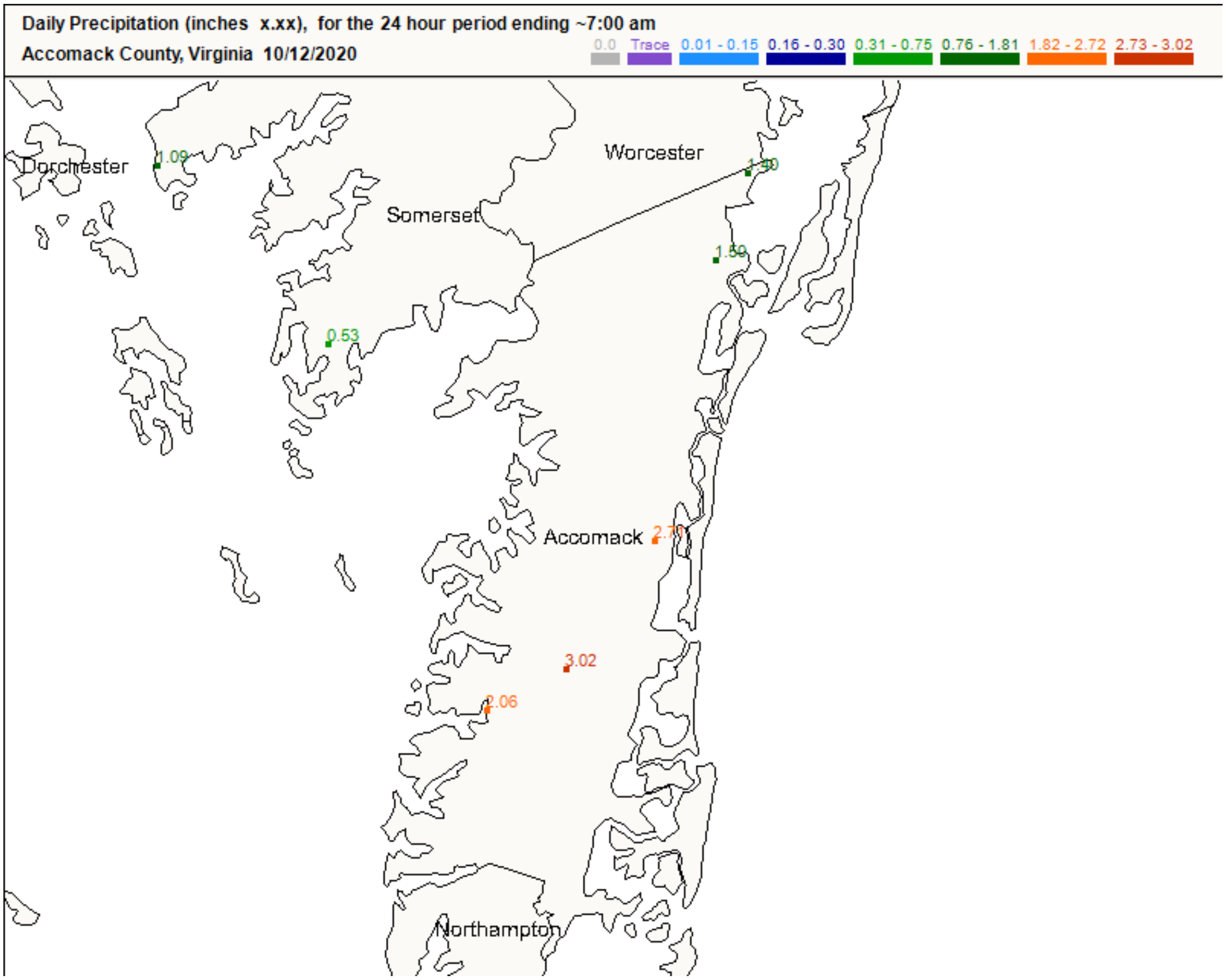

Figure 3. Rainfall records for the event 12 October 2020. Samples were being taken after these readings but before the storm completely passed. Map and data from: https://cocorahs.org/Maps/ViewMap.aspx?state=usa

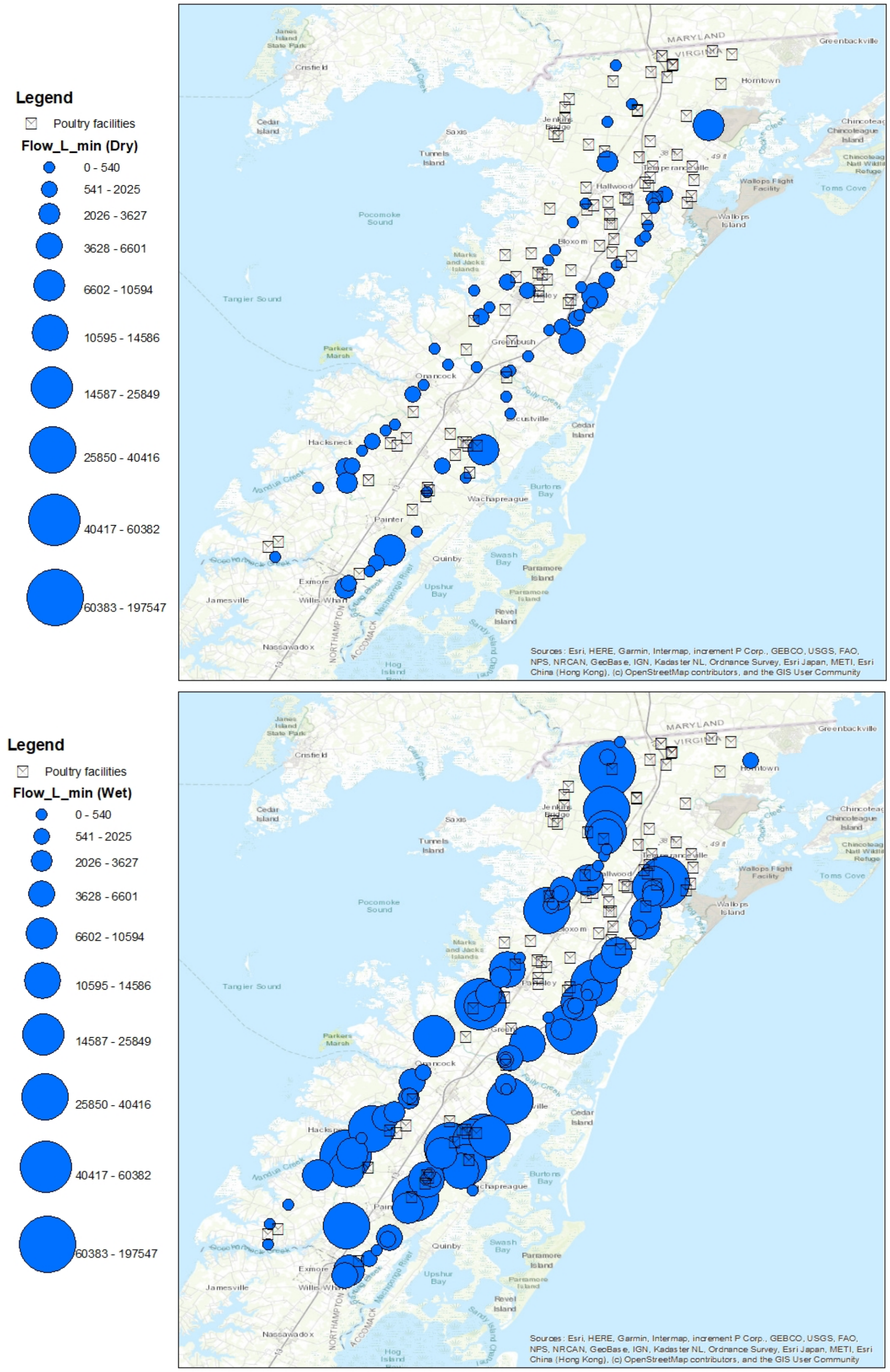

Figure 4. Flow rates in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2” rain events (Bottom; Storm Flow).

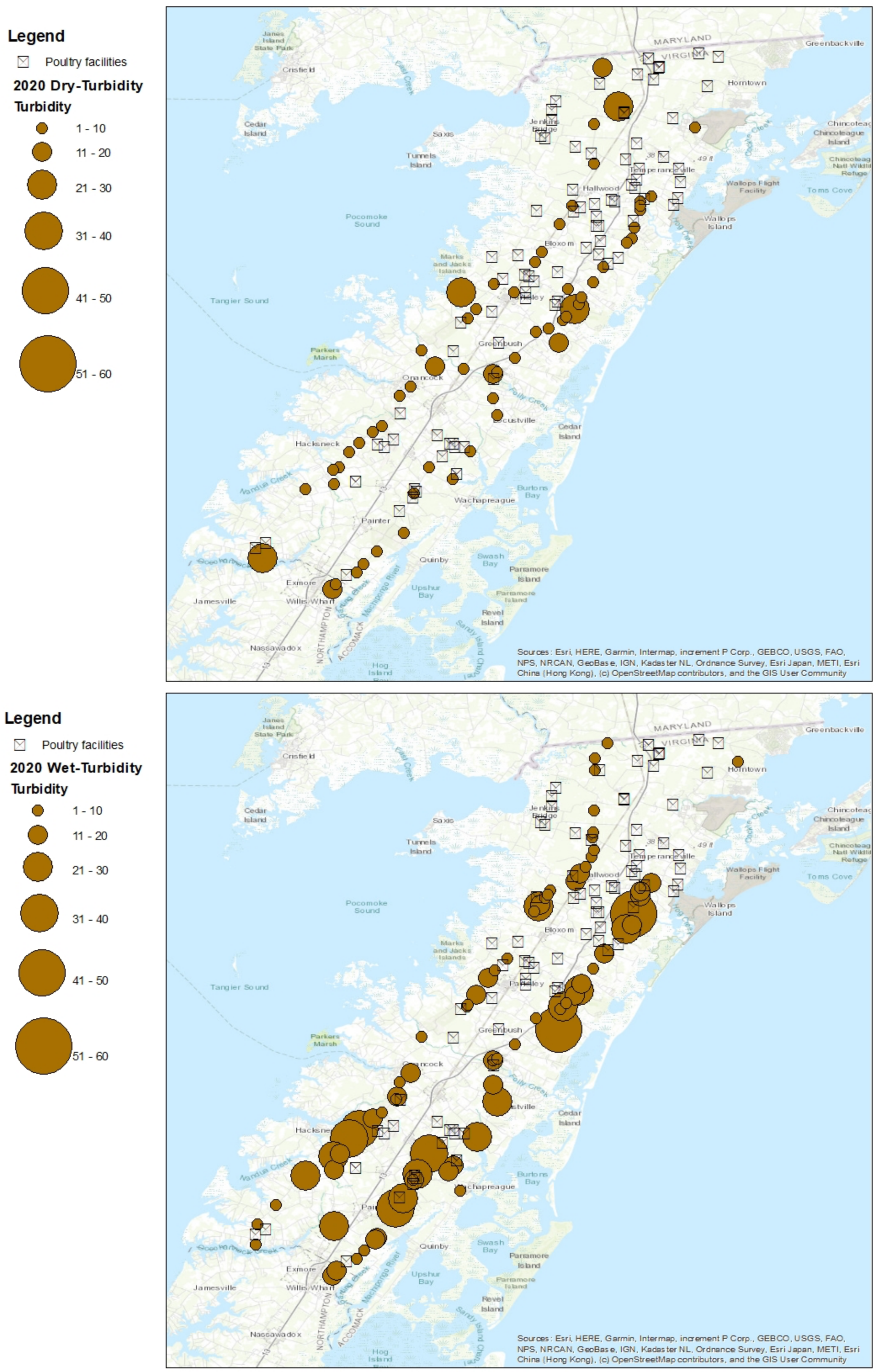

Figure 5. Turbidity in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2” rain events (Bottom; Storm Flow).

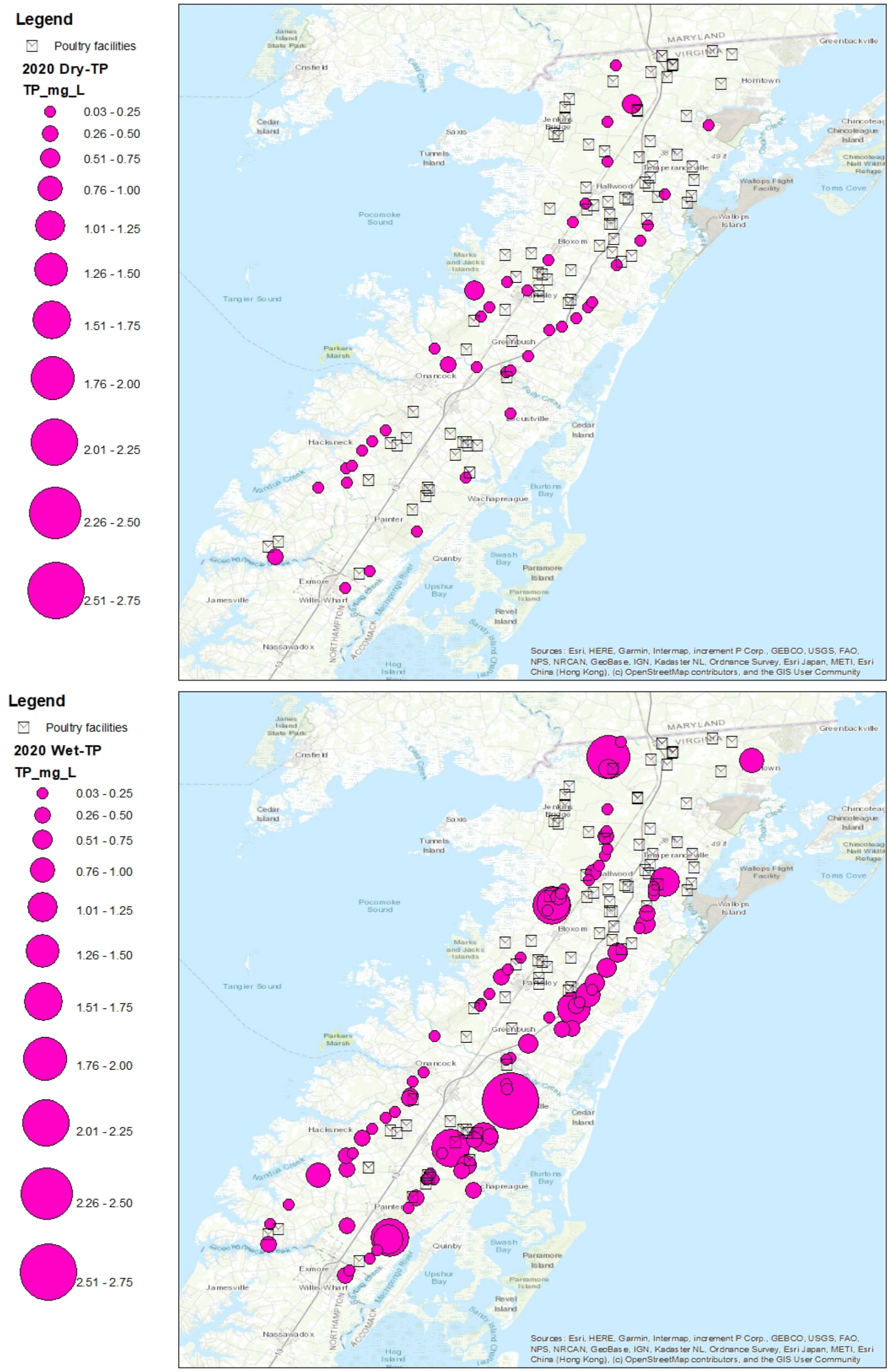

Figure 6. Total Phosphorous concentrations in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2” rain events (Bottom; Storm Flow).

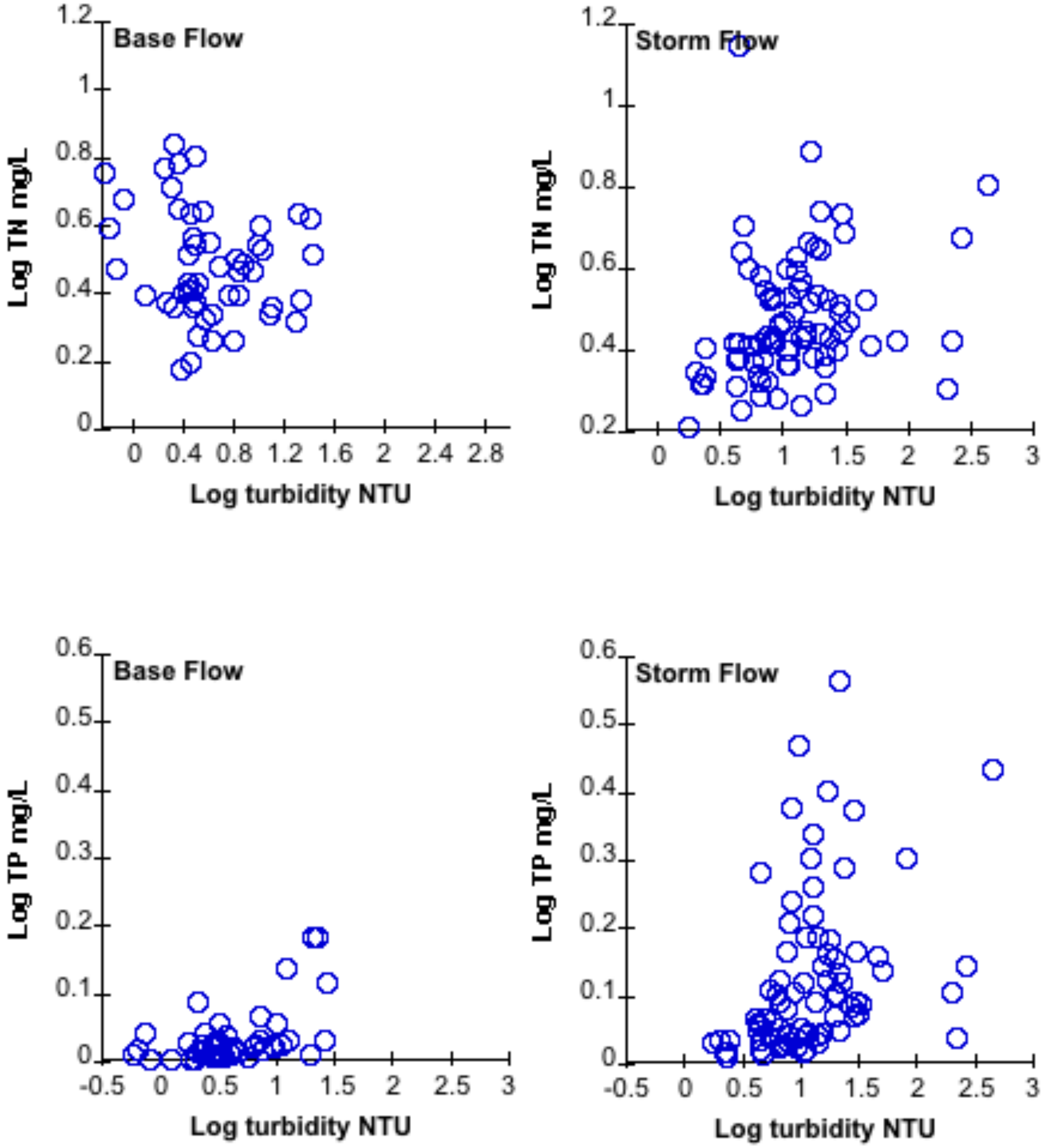

Figure 7. Total Nitrogen (TN) and Total Phosphorous (TP) relative to Stream water Turbidity values for base flow during drought and storm flow following 2” rain events.

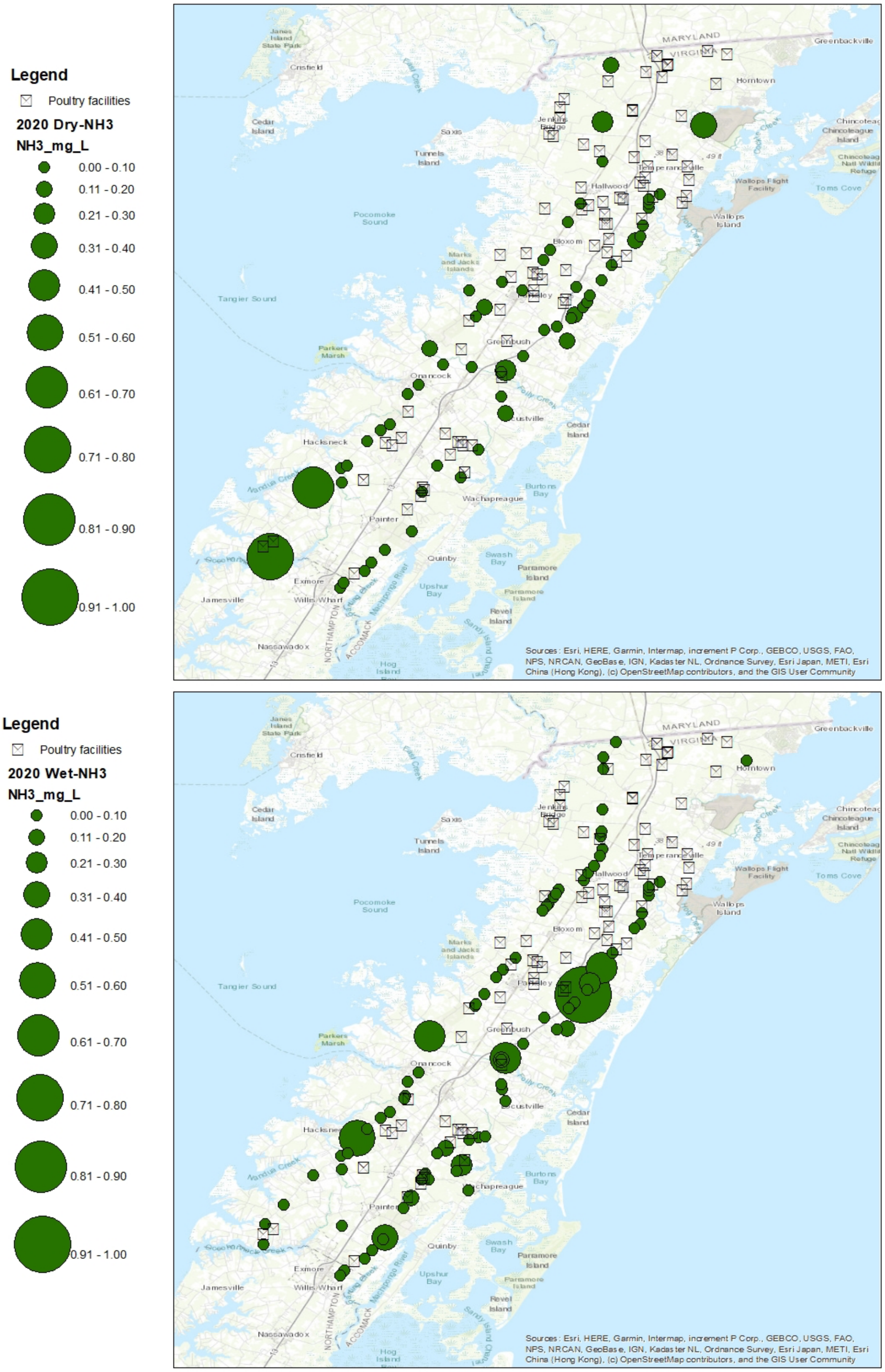

Figure 8. Dissolved Ammonia concentrations in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2" rain events (Bottom; Storm Flow).

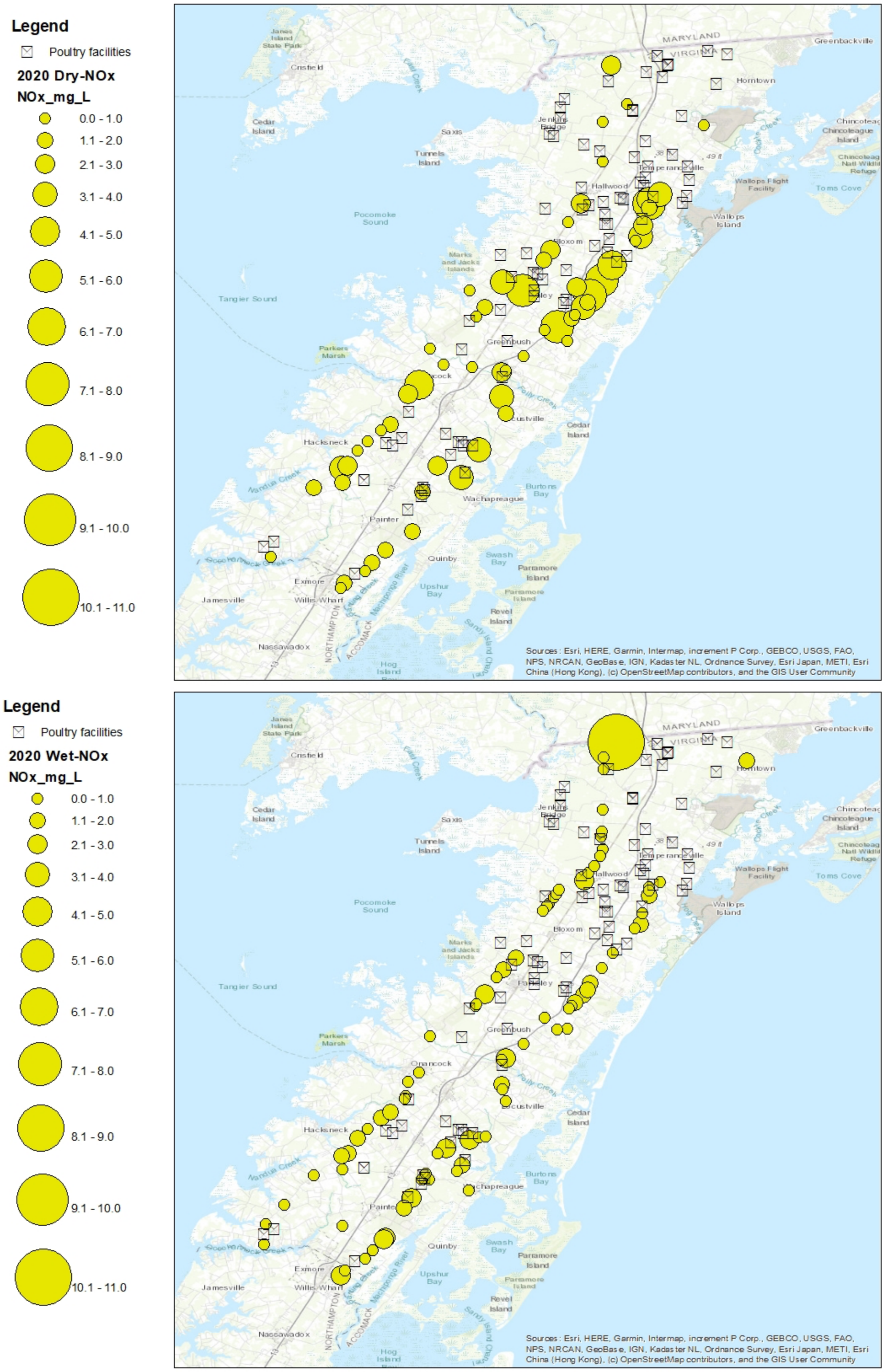

Figure 9. Dissolved Nitrite + Nitrate concentrations in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2" rain events (Bottom; Storm Flow).

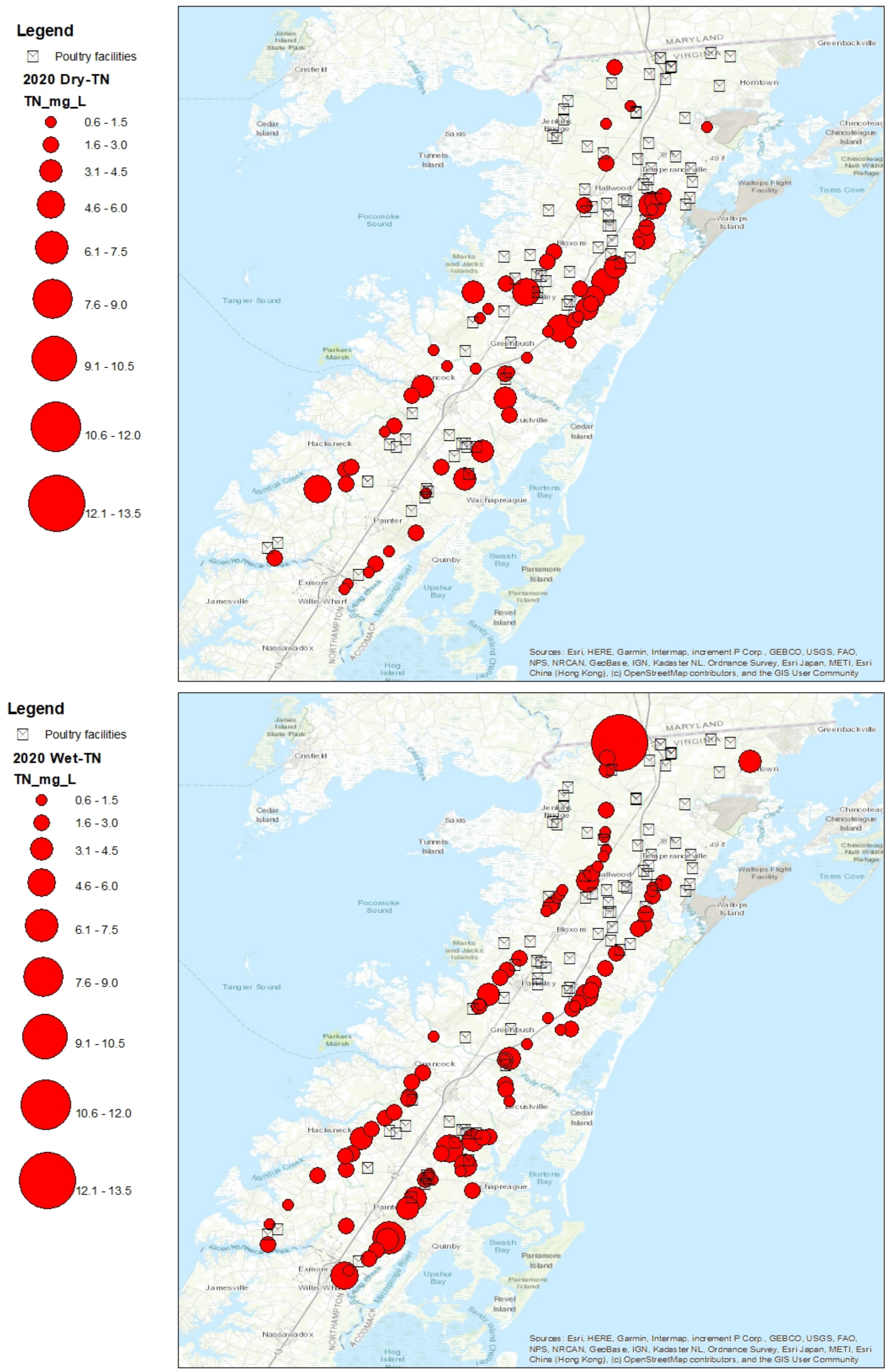

Figure 10. Total Nitrogen concentrations in Accomack streams during a prolonged drought (Top chart; Base Flow), and after 2” rain events (Bottom; Storm Flow).

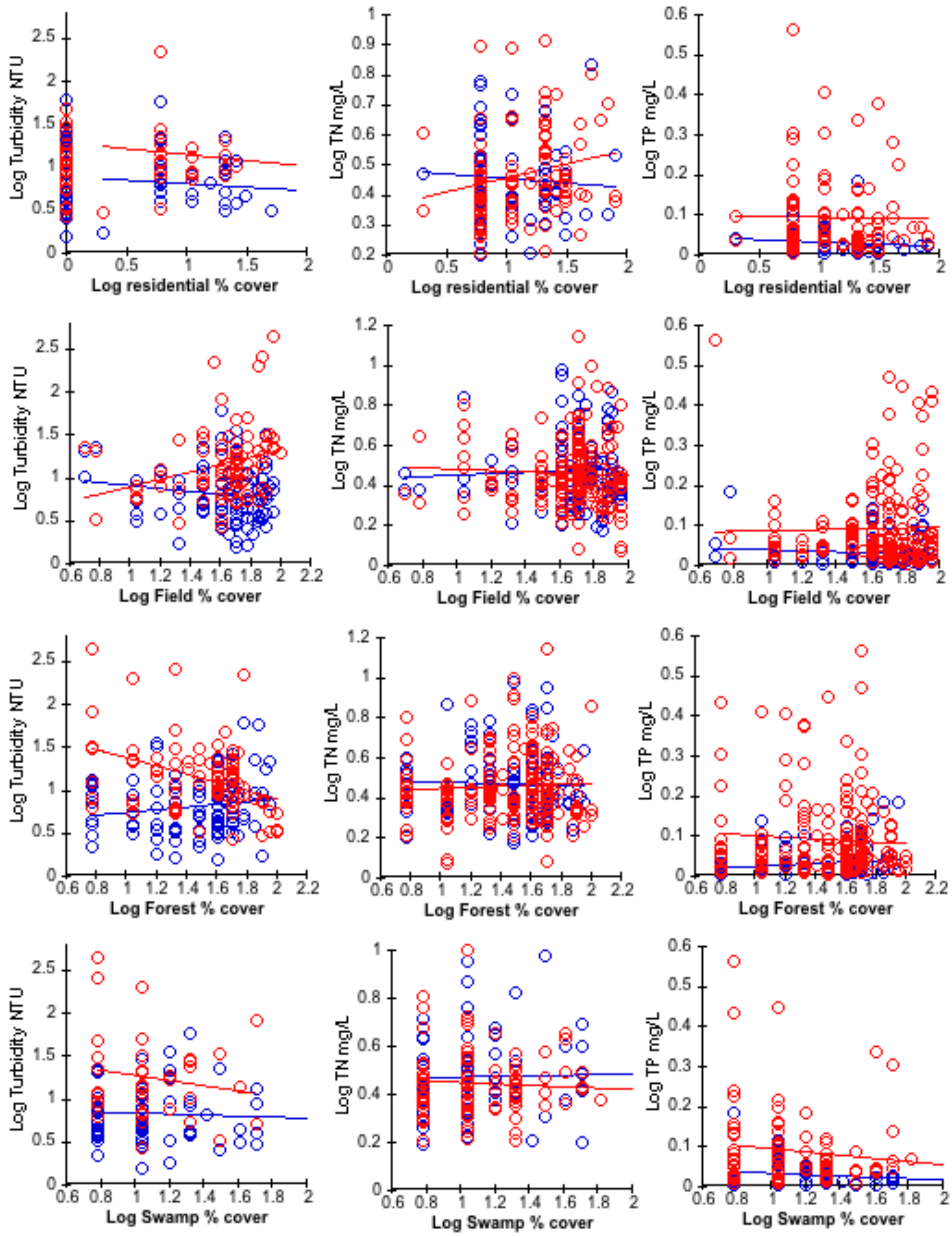

Figure 11. Total Nitrogen (TN) and Total Phosphorous (TP) concentrations in stream water relative to land use cover variables, base flow during drought (blue), and storm flow following 2" rain events (red). Zero values were removed for these plots. Lines represent least square variance regression best fits.

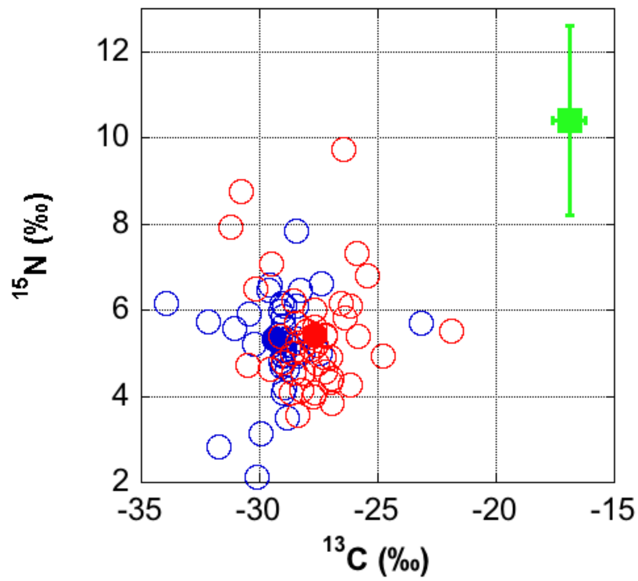

Figure 12. Carbon and Nitrogen stable isotope analysis of stream water particulates from base flow (blue) and storm flow (red), averages are shown as solid symbols of the same colors. Nitrogen and carbon isotope values for Delmarva chicken litter (Fertig et al., 2014) are presented as the average and standard deviations in green. Atmospheric ammonia deposition nitrogen values have been estimated to be 10 to 15 ^{15}N per mil (Fertig et al., 2014).